

REDUNDANT COOLING SYSTEM WITH TWO COOLING CIRCUITS FOR
AN ELECTRIC MOTOR

5 The invention relates to a redundant cooling device for an electric liquid-cooled submarine drive motor, with a first cooling circuit and a second cooling circuit, by means of which thermal energy can be transported away from the electric submarine drive motor.

10 The invention is based on the object of providing a redundant cooling device of high capacity for an electric submarine drive motor, it being intended with the amount of heat that is to be removed to use adapted coolant flows to provide a high degree of operational
15 reliability and redundancy.

This object is achieved according to the invention by the first cooling circuit and the second cooling circuit of the redundant cooling device being designed
20 in the region of the electric submarine drive motor in such a way that the coolant of the first cooling circuit and the coolant of the second cooling circuit flow in opposite directions through a stator cooling ring in which the cooling circuits are arranged. This
25 counter-current flow of the two cooling circuits in the region of the submarine drive motor has the effect that heat is dissipated from it much more uniformly than is possible with cooling devices known from the prior art.

30 In order advantageously to satisfy the requirements in terms of operating conditions imposed on an electric submarine drive motor with regard to the different power output, it is expedient to assign to each cooling circuit a main pump and a minor pump with considerably
35 lower power in comparison with the main pump, the main pump and the

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minor pump of each cooling circuit advantageously having supply voltages that are independent from each other.

- 5 Correspondingly, to increase the efficiency of the overall drive system, each circuit can be operated in a low speed range of the electric submarine drive motor exclusively by means of the minor pump assigned to it and in a speed range above the low speed range of the
10 electric submarine drive motor exclusively by means of the main pump assigned to it.

If transfer lines in which a coupling valve is respectively arranged are provided between the two
15 redundant cooling circuits, the coupling valves can be connected through in the event of failure of a cooling circuit, for example because of failure of the pumps or pump motors, it then being possible for the circulation of the coolant of both cooling circuits to be
20 accomplished by the pumps that are still working.

Since in this case only reduced pumping capacity with a correspondingly reduced current flow is available, the output power of the electric submarine drive motor
25 should expediently be adaptable to the amount of heat which can then be removed.

The redundant pump units, heat exchangers, fittings, valves, etc. belonging to the redundant cooling device
30 are expediently arranged on the upper part of the electric submarine drive motor.

According to an advantageous embodiment of the redundant cooling device according to the invention,
35 each of the two cooling circuits also has a cooling branch by means of which inverter modules assigned to the submarine drive motor can be cooled.

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In both cooling circuits, the coolant may be provided in the form of fresh water to which there may be added an anticorrosive agent, and possibly

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further additives for biologically and chemically stabilizing the water, and which can be re-cooled with respect to each cooling water circuit by means of sea water in a water-water heat exchanger or in a water-air
5 heat exchanger.

The controlling and switching of the main and minor pumps of each cooling circuit expediently takes place by means of a power supplying and switching unit, the
10 dedicated cooling plates of which can likewise be cooled by means of a further cooling branch of each cooling circuit.

According to an advantageous embodiment of the
15 redundant cooling device according to the invention, the motors of the two minor pumps are operated with a fixed supply frequency and/or supply voltage.

According to a further advantageous embodiment of the
20 redundant cooling device according to the invention, the main pump of each cooling circuit is supplied via inverters, in order to adapt the delivery rate of the cooling liquid, and with it the amount of heat to be removed, via the variable speed of the motors. The
25 motors of the main pumps are operated in such a way that their speed and power can be adapted to the amount of heat to be removed.

The use of three-phase squirrel-cage asynchronous
30 motors provides advantageous solutions. The speed and power adaptation of the asynchronous motors with squirrel-cage rotors can take place in an advantageous way by varying the supply frequency and/or the supply voltage and/or by using pole-changing motors.

35 An independent supply voltage is advantageously provided for each of the main and minor pumps.

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Each cooling circuit is expediently equipped with an expansion vessel for the cooling liquid, a device for degassing the cooling liquid, a service connection and advantageously a pressure-relief valve.

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Temperature sensors are advantageously arranged in each of the two cooling circuits for controlling the pump output.

10 To ensure that the components to be cooled are supplied with the appropriate amount of coolant, a pressure-independent flow governor is advantageously arranged in each of the two cooling circuits upstream of the stator cooling ring, inverter modules and the power supplying
15 and switching unit.

According to a further advantageous embodiment of the redundant cooling device according to the invention, a temperature-controlled three-way valve is present in
20 each of the two cooling circuits.

In addition, it is expedient if a nonreturn valve is respectively provided in the pressure side of the minor pumps and the main pumps.

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Furthermore, in an advantageous development of the redundant cooling device according to the invention, quick-action couplings that shut off in both directions are arranged in the connecting lines between the
30 redundant cooling device and the submarine drive motor.

The invention is explained in more detail below on the basis of an embodiment with reference to the drawing, in the single figure of which an exemplary embodiment
35 of a redundant cooling device according to the invention is represented in principle.

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An embodiment of a redundant cooling device according to the invention shown in the single figure serves the purpose of cooling a submarine drive motor 1.

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For this purpose, the redundant cooling device has two cooling circuits 2, 3, which are independent from each other and of which the first cooling circuit 2 is represented on the left of the submarine drive motor 1 and the second cooling circuit 3 is represented on the right of the submarine drive motor 1 in the single figure.

The first cooling circuit 2 flows clockwise through the stator cooling ring 4 of the submarine drive motor 1 in the exemplary embodiment shown in the figure, whereas the second cooling circuit 3 flows counterclockwise through the stator cooling ring 4 of the submarine drive motor 1.

Otherwise, the two cooling circuits 2 and 3 correspond with regard to their configuration, so that only the first cooling circuit 2 will be explained in more detail below with regard to its individual components, etc. The second cooling circuit 3 is constructed in a corresponding way, its functions also being correspondingly configured.

The first cooling circuit 2 has a main pump 5 and a minor pump 6, the output of which is significantly less in comparison with the main pump 5.

By means of the minor pump 6, the coolant circulation can be accomplished in a part-load range of the submarine drive motor 1. The main pump 5 of the first cooling circuit 2 remains switched off at that time.

In the exemplary embodiment represented, the main pump 5 of the first cooling circuit 2 is operating above the part-load range of the submarine drive motor 1. The minor pump 6 can be switched off at this time. Motors 7 and 8 of the minor and main pumps 6 and 5, respectively, are designed in the exemplary embodiment

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represented as asynchronous motors with squirrel-cage rotors. The two motors 7, 8 of the minor pump 6 and main pump 5 of the first cooling circuit 2 are assigned a power supplying and

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switching unit 9, the electrical part of which is not represented in the single figure and can be varied according to demand by means of the supply frequency and/or the supply voltage.

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For the motors 8 of the main pumps 5 and the motors 7 of the minor pumps 6 of the two cooling circuits 2, 3, an independent supply voltage is respectively provided.

10 Between the two redundant cooling circuits 2, 3, two interconnected transfer lines 10, 11 are provided. Respectively arranged in these two transfer lines 10, 11 is a coupling valve 12 and 13, the switching-over of which can take place by means of a common hand lever.

15 When the coupling valves 12, 13 are open, it is possible to operate the two cooling circuits 2, 3 by means of a single main pump, for example by means of the main pump 5, i.e. the coolant circulation can be maintained in both cooling circuits 2, 3 by means of a

20 single main pump 5. In this operating state, only a smaller total amount of coolant can be circulated on the submarine drive motor 1, so that the power of the submarine drive motor 1 is to be reduced in a way corresponding to the amount of heat that can then be

25 removed.

In both cooling circuits 2, 3, the re-cooling of the coolant takes place in each case by means of a water-water heat exchanger 17, in which the coolant of the

30 cooling circuits 2, 3 is re-cooled by means of sea water.

The two water-water heat exchangers 17 as well as the two main pumps 5 and the two minor pumps 6, expansion

35 vessels 21, pressure-independent flow governors 16, 19, 20 and all the required fittings of the two cooling circuits 2, 3 are constructed on the submarine drive motor 1.

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The cooling circuits 2, 3 each have a cooling branch 14, by means of which inverter modules 15 arranged in it can be cooled. Arranged upstream of the inverter modules 15 in this cooling branch 14 is the pressure-independent flow governor 16.

The power supplying and switching unit 9 of each cooling circuit 2, 3 is arranged in a further cooling branch 18 of the first cooling circuit 2 and the second cooling circuit 3, respectively, the further pressure-independent flow governor 19 being arranged upstream of the power supplying and switching unit 9 in this further cooling branch 18.

In addition, in each of the two cooling circuits 2, 3, the further pressure-independent flow governor 20 is provided upstream of the stator cooling ring 4 of the submarine drive motor 1.

Present in each of the cooling circuits 2, 3 is the expansion vessel 21, in which the cooling liquid can expand and degas via a degassing device 27.

On this expansion vessel 21 there is also a service connection 22, for example for filling the cooling circuits 2, 3.

To protect the cooling circuits 2, 3, a pressure-relief valve 28 is present in each of the cooling circuits 2, 3.

In addition, a temperature sensor 23 is installed in the expansion vessel 21 for the temperature-dependent control of the minor pumps 6 and main pumps 5.

Since, when respectively operating only one main pump 5 or one minor pump 6 in the cooling circuits 2, 3, return of the coolant flows via the main pump 5 or

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minor pump 6 that is not in operation must be prevented, corresponding nonreturn valves 24 are respectively installed in the pressure lines downstream of the main pump 5 and minor pump 6.

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In order to prevent condensation inside the submarine drive motor 1 during its operation, the re-cooling of the cooling liquid by means of sea water via the water-water heat exchanger 17 is controlled by means of a
5 temperature-controlled three-way valve 25.

In order to facilitate ease of maintenance and accessibility to the submarine drive motor 1, all the connections between the components of the redundant
10 cooling device on the upper part of the submarine drive motor 1 and the submarine drive motor 1 are provided with quick-action couplings 26 which automatically shut off on both sides.